ECONOMIC PROBLEMS IN AGRICULTURE BY IRRIGATION

I. THE IMPORTANCE OF AGRICULTURE BY IRRIGATION

Agriculture by irrigation presents some of the most interesting as well as some of the most difficult problems found in the field of agricultural economics. It has been with enormous rapidity that the frontier of American agriculture has moved westward during the past century. One by one new conditions have presented new problems which had to be met and solved. The westward movement long since reached the arid region. The new economic problems here presented to the homeseeker center about the organization of agriculture by irrigation. While the greater part of the arid West must ever remain relatively fruitless, the favored spots where irrigation can be practiced are becoming the centers of the most profitable and the most progressive agriculture in America.

Without irrigation the land of the arid states would be valued according to the profits of the grazing industry which could be based upon it, and this would probably not exceed, on the average, $1.25 an acre. Some of the best, irrigated land in Colorado sells for $300 per acre, some of the hop lands of the Yakima Valley in Washington sell for $700, and citrus-fruit lands in California sell for as high as $1,800 per acre.

But the profits of agriculture by irrigation are not confined to those special crops, which are, it is true, more especially adapted to this form of agriculture because they are crops requiring intensive culture. The ordinary farm crops are being produced with great profit in the irrigated regions. Wheat, oats, barley, hay, and potatoes are grown almost exclusively by irrigation in seven of the Rocky Mountain states, namely: Montana, Wyoming, Colorado, New Mexico, Arizona, Utah and Nevada. It is true that when the figures showing the quantities of these crops produced in the arid states are compared with those of the United States as a whole, they seem relatively small; yet in themselves 32,000,000 bushels of grain, 13,000,000 bushels of potatoes, and 4,500,000 tons of hay, with an aggregate value of more than $60,000,000, are an important contribution to the nation's annual income.

The average returns of these five crops in the seven Rocky

Mountain states have been compared with the averages for the same group of crops for the remainder of the United States. The figures are based upon those given in the *Yearbook* of the Department of Agriculture for 1904. The figures show clearly that the average value per acre of crops is much greater in the states where irrigation is commonly practiced than in the humid regions. The average return of the area devoted to grain, hay, and potatoes in the seven States is $19.82 per acre, whereas the average for the remainder of the United States is $12.55—an advantage in the favor of agriculture by irrigation of $7.27 per acre. The advantage in the case of wheat is $11.82 per acre, and in the case of potatoes $17.40 per acre.

According to the last report on the "Progress of the Sugar Beet Industry in the United States," [1] the area of sugar-beets harvested in the United States in 1904 was 197,784 acres, 105,000 acres, or 53 per cent., of this area being in the four states of California, Colorado, Idaho, and Utah, in which irrigation is necessary to sugar-beet production. Owing to the higher average yield of sugar-beets per acre and to the higher average percentage of sugar in the beets grown in these irrigated states this 53 per cent. of the total area yielded over 60 per cent. of the total quantity of sugar manufactured. The return to the farmer was $54.18 per acre in the arid states, and $39.15 in the remainder of the United States, leaving a balance in favor of beet production by irrigation to the amount of $15.03 per acre.

When the returns per acre in the irrigated areas in the United States devoted to these six crops—barley, hay, oats, potatoes, sugar-beets, and wheat—are compared with the average returns per acre on the areas devoted to these crops in the remainder of the United States, it is found that the general average returns on the former area is about $21 per acre, while that for the latter is about $12.50, showing a general average advantage of $8.50 per acre in favor of irrigation. This does not mean, of course, that agriculture by irrigation yields larger returns per unit of labor and capital invested; so far as these figures are concerned, the reverse might be true. But these figures do emphasize the fact that agriculture by irrigation seems to warrant a larger investment per acre of land in the production of the crops named, than does the agriculture of the humid regions of the United States.

[1] *Report No. 80*, U. S. Department of Agriculture.

The crop returns in the seven Rocky Mountain states (Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, and Nevada), compared with those for the remainder of the United States, in 1905, are as follows:

AVERAGE VALUE OF CROPS PER ACRE

Crop	Rocky Mountain Region	Remainder of the United States	Difference in Favor of Irrigation
Barley	$23.16	$11.24	$11.82
Hay	17.69	13.01	4.68
Oats	16.41	9.96	6.45
Potatoes	66.52	49.12	17.40
Sugar beets*	54.18	39.15	15.03
Wheat	21.32	11.44	9.88
General average	20.97	12.47	8.50

*California and Idaho are included in case of sugar beets.

The area for which we have figured these average returns represents only about one-third of the total irrigated area in the United States. According to the census figure for 1902, about 9,500,000 acres of land were irrigated in the United States. There has been some increase since that time in the area irrigated, but to make our estimate conservative we have multiplied this area by the general average returns described above, which gives a total product of nearly $200,000,000 for the entire irrigated area. That $200,000,000 is a very conservative estimate will be appreciated when it is remembered that these are crops which generally yield relatively small returns. The vast fruit industries of all the irrigated states have not been included in the figures used for calculating this general average, and could statistics for these crops be secured and included, the average return might be much above $21 per acre. But assuming $200,000,000 to be a fair estimate of the farm value of the crops grown upon irrigated land, this would be by no means the whole truth as to the importance of agriculture by irrigation. To this must be added the industries that are based upon these crops and the many indirect results of irrigation.

The range live-stock industry has been greatly influenced. In the early days the live stock had to depend upon the range in winter as well as in summer and great losses were common because of the lack of a winter food-supply. At the present time the range is supplemented by the production of alfalfa hay for winter feed, and the range industry has been insured against heavy losses. Not only

is the industry secure, but the products are of a higher quality, the lambs fed in Colorado being noted for their fine quality.

Likewise the mining interests have been greatly influenced by agricultural development resulting from irrigation. The presence of a relatively cheap food-supply in the Rocky Mountain region has made possible the exploitation of many natural resources of that region which could not have been so extensively developed had it been necessary to depend upon eastern states for food-supply.

More general, and yet equally important, has been the influence of agriculture by irrigation upon the transportation lines from East to West. The agricultural products and the increased mineral products have an important influence upon the profits of railway-building, making it possible to have much better means of transportation through these regions than could have been built without the profit due to the population and industry made possible by irrigation. A good example is the influence of the fruit industry of southern California upon the transportation lines between that region and Chicago.

Agriculture by irrigation is developing a new type of farmer. There are several reasons for this: (1) relatively large investments are necessary to this form of agriculture; (2) the profits due to superior efficiency as a manager are very large, while the losses due to careless management are sufficient to eliminate the negligent farmer; and (3) the opportunities for planning the work of the farm, as if it were a factory, are much better than in the humid regions, because the water-supply can be so regulated that the field operators move on regularly from seed-time to harvest. Where the farmer is secure in his right to an adequate supply of water, the chance element is less also with regard to quantity of crops produced. While the operator of the irrigated farm is surrounded by forces and conditions which seem not only to make possible, but even to compel, development of the business side of agriculture, he is at the same time confronted with difficult problems of his own.

II. ECONOMICAL USE OF WATER IN IRRIGATION

Agriculture by irrigation, as well as agriculture under less artificial conditions gives rise to two classes of economic problems. In the first class are those problems which confront the farmer in his efforts to select land, choose crops, and regulate the proportions between land, water, labor, and equipment in such manner as will

enable him to secure the largest total net profits. In the second class are those problems which confront the statesman whose duty it is to formulate laws, and institutions which will set such limitations on free actions of individuals as may be required to bring their actions into harmony with the interests of society as a whole.

There is manifestly a close relation between these two classes of problems. It is necessary that the statesman shall understand the motives and actions of individuals when left to do as they please. It is also necessary that he shall have a clear comprehension of the actions required of the individual to secure the highest degree of social well-being.

It is perhaps true that the primary function of public authority is, through its laws and institutions, to bring the actions of individuals into harmony with the interests of society as a whole, but another function of the state is the education of the farmers to know and to do that which is, at the same time, in their own interest and in the interest of society as a whole. To take a familiar instance, for example, it may be to the interest of Farmer D, in an irrigated region, to take from the stream the water which Farmer C has long used. This may enable Farmer D to convert relatively worthless lands into fruitful fields, but it will be at the expense of farmer C, whose fields would be fruitless and whose improvements would be rendered worthless. Thus it is that freedom on the part of each farmer, to follow his own interest in the appropriation of water, would lead to the destruction of property. It has, in fact, been true in the irrigated regions, as is generally known, that lack of state regulation has resulted in a sort of anarchy. The farmers have at times resorted to their guns to enforce what they looked upon as their rights. Laws regulating the appropriation of water are manifestly necessary to the well-being of society in the arid West.

Under proper regulation of the water-supply, it may be to the interest of the farmer to use water with that degree of economy which makes the water-supply add most to the national wealth, and yet because of ignorance of his best interest the farmer may fail to live up to this ideal. It is not a simple problem to make sure that the water is used on the proper land, in the production of the proper crops, and in the proper quantities per acre to enable the farmer to secure the best results. It is very important, therefore, to carry on those lines of investigation which will lead to the education of the

farmers in the economical use of water. These are problems which are important in every branch of agriculture; but in agriculture by irrigation, where the farmers are required to act together to secure their water-supply, and where the investments are relatively very large per acre, both regulation and education are exceedingly important.

The economic problems involved in the use of water whether viewed from the standpoint of the individual farmer or from the standpoint of the nation as a whole, may be included under four heads: (1) On which land should the water be used? (2) To which crops should the water be applied? (3) How should the water be applied? (4) How much water should be used per acre in the production of a given crop?

1. *On which land should the water be used?*—The social ideal is the largest gross return from the sum-total of the resources of the country. The goal of the individual farmer is the largest total net profit.

The supply of irrigable land is very great when compared with the supply of water which can be used for purposes of irrigation. Since only a small part of the land can be irrigated, on which land should the water be used? Should it be used on the land which is most fertile when irrigated? Not necessarily, because such land may be located far from the market, so that less fertile land near the market may enable the user of the water to secure larger returns in values. But, again, where the fertility and the distance from the market are the same, one piece of land may be much more accessible than another for purposes of irrigation, and for this reason enable the user of the water to secure larger returns for his investment. Fertility and location, location with respect to the market and with respect to the water-supply, are the physical factors which underlie productivity. By productivity of the land is meant its value-producing power per unit of expenditure for productive purposes.

Shall we say, therefore, that the water should be used upon the most productive land? From the standpoint of the individual farmer, this question may be answered in the affirmative, for this would enable him to win the largest total net profit. If the water of a stream were used once for all and the location of its use affected only the land on which it is first applied, this use would conform to the social as well as to the individual ideal. But it is said to be true that with present methods of irrigation the same water may be used

several times for purposes of irrigation; that a large percentage of the water put upon the land finds it way, by seepage, back to the stream and may be diverted by those whose head gates are farther down the stream. Other things being equal, the water-supply of a given stream can be made to yield the largest results for the nation when it is diverted as it first emerges from the mountains. This will give the greatest opportunity for return seepage and secondary and tertiary diversion before the stream passes from the arid to the humid regions.[2] This use of the water is likewise most desirable when viewed from the standpoint of losses from the stream due to evaporation.

The problem of where the water should be used in order to secure the best results is, therefore, a very complex one; and even if the individual farmers were capable of making the right choice of land, it is by no means clear that their interests would coincide with the social ideal.

2. *The crops for which the water should be used.*—Having selected the land, the next problem is to ascertain which crops should be grown in order that the best results may be secured. The value of the crop per acre of land, the value of the crop per unit of water used, the net profit per acre of land, and the net profit per unit of water used, have each been taken by different men, and even by the same man at different times, as a standard by which to estimate the relative profitableness of the different crops which will thrive. When the subject is viewed from the standpoint of the individual farmer, whose purpose it is to secure the largest total net profit in return for the time and energy which he puts into agricultural production, none of these criteria would necessarily prove correct. In the first place, the crop which yields the highest return per unit of land may require such large quantities of water that the return per unit of water is relatively small; and, again, it may prove true that the crop which yields the highest gross return in value per acre may require such large investments of labor and capital that the net return per acre may be relatively small. The same criticism may be made if the largest gross return per unit of water be taken as the standard. It may prove true, moreover, that neither the crop which yields the largest net profit per acre nor that which yields the largest net profit per unit of water used will enable the

[2] See *Bulletin 157*, U. S. Department of Agriculture, Office of Experiment Stations.

farmer to secure the largest total net profit for his time and energy. For example: Sugar-beets may yield a higher gross return per acre and per unit of water, and at the same time yield a larger net profit per acre and per unit of water used, than alfalfa, and yet it may prove true that a given farmer can secure a larger net profit per unit of time and energy devoted to alfalfa than to sugar-beets. This may be true for the reason that sugar-beets require much more labor and managerial activity per acre of land, or per unit of water used, than alfalfa. The farmer who follows business principles will subtract from the total gross returns secured from a given crop the total expenditures for the use of the land, water, and machinery, and for labor in case he hires any. This gives the net profit to be secured from this crop. This net profit should be compared with that to be secured from another crop to which the same time and energy may be devoted. This will require careful accounting, and yet it is essential if the farmer is to ascertain which crops are most profitable. In this comparison of the profitableness of crops, one factor should be taken into account. Different crops require water at different seasons. It is likewise true that different crops require the attention of the farmer at different times in the year. Crops requiring the attention of the farmer at the same time of the year may be called *competing crops,* because they compete for the time of the farmer. When the crops have been classified into groups of competing crops, these groups may be called *non-competing groups* because each member of the groups requires the time and attention of the farmer, his horses, tools, machinery, and water-supply at different times of the year. Sugar-beets and potatoes may be given as one group of competing crops; winter wheat and rye, as another; spring wheat, oats, and barley, as another. From a given group of competing crops the farmer should select that one which, one year with another, will add most to his net profits.

It may be true that the most profitable crop in the spring-grain group yields the farmer a smaller net profit per unit of time and energy than he is able to secure by the production of the most profitable of the root crops and yet, since they require his attention at different seasons, his total net profit for the year will be much greater when he cultivates both crops than when he confines his attention to the one which yields the highest net profit per unit of energy devoted to its production.

It is a well-recognized fact that the different crops make different demands upon the soil. For this reason the crops which are associated together in the systems of rotation should be such as will make supplementary demands upon the soil's elements of fertility. This in itself, however, is not a safe guide in determining which plants should be introduced into the field system; for it might lead to the cultivation of the less profitable of two competing crops, and thus reduce the farmer's total net profit. Yet it should ever be kept in mind that if one of two competing crops exhausts the soil, while the other adds to its fertility, this must be taken into account when calculating the net profit which these crops can be made to yield. The crops being chosen which will, one year with another, enable the farmer to win the largest net profit, they should be arranged in the field system in such a manner as best to supplement each other in their demands upon the soil.

Thus far it has been assumed that the water-supply, like the time of the farmer must be used as it passes by. This is not exactly true. The relatively high value of water in July and August has led to a desire on the part of owners of water rights in Colorado to store some of the water, which they have a right to use on grain crops in May and June, to be used on root crops later in the season. This practice has been objected to on the ground that the law states specifically that

> persons desiring to construct and maintain reservoirs, for the purpose of storing water, shall have the right to take from any of the natural streams of the state and store away any unappropriated water not needed for immediate use for domestic or irrigation purposes.[3]

That it is economically desirable to store water which would otherwise be used in the irrigation of wheat, when the greater value of water used later in the season justifies the expense, will, doubtless, be quite readily granted. The objection arises from the fact that, once established, there is thought to be danger that this will lead to the expansion of earlier rights at the expense of the later appropriators. Whether or not this fear is well grounded depends mainly upon the efficiency of the administrative system. Water storage is expensive, and it is only when the high profits to be derived from the growing of the root crops enable the farmers to pay high prices for its use, that the practice is economical. And yet, when the

[3] Mills's *Annotated Statutes,* sec. 2270.

farmer's profits can be increased by storing the water which he has a right to use in the wheat-irrigation season, and using it later for the irrigation of roots, it would seem that irrigation laws should not be so formulated as to prohibit this use of the water. The laws which apparently prohibit this practice will be recurred to later. Our aim here is to state principles.

With freedom to use his land and his water-supply at the time, and in such a manner as will enable him to secure the largest net profits, the farmer should select from each group of competing crops that one which enables him to add most to his net profit, and every group should be represented in the field system if the most profitable crop in the group adds a sufficient amount to the total net profit to pay the farmer for his extra effort.

Does the principle of crop selection which enables the farmer to secure the largest net profit lead at the same time to the best results socially? It seems clear that, when the individual farmer follows the above principle, he in no way limits other individuals from doing likewise. It is true also that this means of securing the highest net profits has no tendency to reduce wages, interest, land values, nor water values, but rather to increase them. It is apparent, therefore, that the choice of crops which enables the farmer to secure the largest net profits is also in harmony with the highest degree of productivity for the resources of the nation as a whole. Unfortunately, few farmers attain to this ideal. The information necessary to rational action is often lacking. The state has an important function, therefore, in securing and disseminating information which will enable the farmers to select those crops which one year with another will yield him the largest net profit.

3. *The methods of applying water.*—The flooding system, the check system, the furrow system, and the pipe and hose system are the most important of the different methods of applying water to land for purposes of irrigation. These methods are given in the inverse order of their expensiveness per unit of water applied. By the cheaper method—that of flooding—a larger share of the water applied to the land is lost by seepage and by evaporation. By the use of pipes and hose both of these losses are reduced to a minimum. The local value of water and the local value of labor are the principal factors which determine which method will prove most profitable. It has been common for irrigation engineers to speak of those methods of irrigation which require much water and little

labor, as wasteful. This is a wrong notion of economy in the use of water. Where water is plentiful and laborers few, the highest degree of economy is attained by that method of application which requires little labor, even if large quantities of water be used. We have here the problem of adjusting the proportions between expenditures for water and for labor in such a manner as will enable the farmer to secure the largest net profits. This is a problem that can be solved only by a system of accounting which will enable the farmer to act rationally.

One point which has often been discussed under this head is the rotation of the water-supply. Where each farmer must take a continuous flow of water, it often happens that the quantity received by each farmer is much less than he is capable of handling. This results in a waste of time and an increased cost of distribution. It has also been pointed out on various occasions that where the farmer receives his water in such small quantites the loss from evaporaton and seepage is greatly increased. A system of rotation in the distribution of water which will give to each farmer, and especially to the small farmer, his water-supply in relatively large quantities for short periods at given intervals, or when he may choose to call for it, rather than a continuous flow of small quantity, is eminently desirable from the standpoint both of public and private economy.

4. *The duty of water.*—The proper quantity of water to be applied to an acre of land in the production of a given crop is referred to by irrigation engineers as the "duty of water." Investigations have been carried on by the United States Department of Agriculture in co-operation with several of the agricultural experiment stations, to ascertain how much water should be applied to a given area of land in the production of a given crop in order that the best results shall be obtained. The method has been to secure several plats of land which have a uniform soil, and to apply water in varying quantities per acre to the different plats in the production of a given crop.

The experiments seem to indicate that to a certain point the produce increases more rapidly than the quantity of water applied, after which the total product per acre can be increased for a time by further additions of water, but a point is finally reached where the total product per acre decreases as the quantity of water applied is increased. This means, of course, that the maximum product per

inch in depth of water applied is reached long before the point of maximum return per acre has been reached. In the production of oats at the Utah station, for example, it was found that the largest product per acre was secured where water was applied in amounts equivalent to 30 inches of rainfall, but the largest product per unit of water was secured when limited to 15 inches. In the production of wheat at the New Mexico station it was found that the largest product per unit of water was secured when limited to 24 inches, but that the product per acre continued to increase until 35.3 inches had been applied.

Thus far the experiments have not been planned with sufficient care. In most cases no account has been kept either of the costs or of the values of the products. But they give ground for the belief that carefully planned experiments may yield results of great value. In the planning of these experiments there is work for the economist and the accountant.

The problem of the economical use of water is not simply that of ascertaining the proportions in which *water* and *land* should be brought together; it involves as well the proportions in which expenditures should be made for cultivation and irrigation. It is believed that irrigation can, to a certain extent, be made to take the place of cultivation, and it is certainly true that surface culture conserves moisture, and thus reduces the quantity of water required to produce a good crop.

We have here the whole problem of the proportions in which the factors of production should be brought together, with one new element added—that of an artificial water-supply. This problem is discussed in works on economics under the captions of "the intensity of culture" and "diminishing returns." Most economists have confined themselves to the one problem of the quantity of labor and capital which should be applied to a given area of land, and have concluded that the intensity of culture should be such that the increase in the total value of the product attributable to the final increment in the outlay shall be just sufficient to pay the cost of this final increment.

Professor Carver [4] has made an advance over other economists by recognizing that the problem is not so simple as this; that the proportion between laborers and equipment, or between horses and machines is an equally important question. That is, if the farmer

[4] *Distribution of Wealth*, chap. ii.

desires to harvest a particular crop, he may choose between several methods: the man and the sickle, where labor predominates over capital; the self-rake, where labor and capital are more nearly equal in importance; and the combined harvester and thresher, where the expenditure for the machine is very great and the number of men employed relatively very small. Or again, if the farmer desires to plow a particular field, he has his choice between the two-horse plow with which one man can plow two acres a day and a steam plow with which two men can plow 100 acres in a day. This is the problem of the proportions in which the factors of producton should be associated. Professor Carver's solution to this problem is as follows:

To ascertain the quantity of labor to be associated with a given quantity of capital in the form of machines, tools, and horses, one should increase the quantity of labor until the product attributable to the last increment of labor is just sufficient to pay the cost of employing that increment. Again, the quantity of capital to be associated with a given quantity of labor should be such that the product attributable to the last increment of capital will be just sufficient to pay the cost of securing the use of that increment of capital. The proportion between these two factors and land is to be ascertained in the same manner. That is, the degree of intensity should be such that the product attributable to the final increment will just pay the cost of securing that increment of the labor and capital; or, what is the same thing according to Professor Carver, the quantity of land cultivated by a given supply of labor and capital should be increased or decreased until the product attributable to the final increment is just sufficient to pay the rent on that increment of land.

If correct, the application of this method to the determination of the proportions in which water, land, labor, and capital should be associated gives a simple solution to this phase of the problem of the economical use of water: Simply increase the quantity of water until the product attributable to the last increment is just sufficient to pay for the water and its application.

But it may have occurred to the reader to ask if the result is always the same whether the quantity of water used on a given area of land be such that the product attributable to the last increment of water is just sufficient to pay the costs involved in its application, or whether the quantity of land irrigated by a given quantity of water be such that the product attributable to the last increment of land is just sufficient to pay the cost of securing the use of the

land, the first would bring the largest net profit per unit of land, the latter the largest net profit per unit of water; and the writer doubts if these two usually coincide.

If it were true that all farmers possessed ability of the same *quality*—that is, if all managers of farms secured the same return per unit of labor and capital operated, and the wages of superintendance were a known quantity which could be added to the cost of applying a given increment of labor and capital to a given piece of land—then (if all crops were equally profitable, which will here be granted only for the sake of concentrating the argument upon the one point—variation in the quality of the management) it would not make any difference whether succeeding increments of land be applied to a given amount of labor and capital until the product attributable to the last increment of land is just sufficient to pay the rent of the last increment of land, or whether succeeding increments of labor and capital be applied to a fixed area of land until the product attributable to the last increment is just sufficient to pay its hire; but it is right here that the complexity arises. Professor Carver's line of thought seems to assume that all men make the same profit per unit of investment in labor and capital, and that this profit is a definite known quantity which may be used in figuring the proper degree of intensity of culture. On the other hand, the writer believes that *the farmer's profit is an indefinite residuum which it is the desire of the farmer to make as large as possible, and which will vary with the quality of the farmer's managing ability.* This being true, Professor Carver's method of ascertaining the proper degree of intensity of culture cannot be applied to the problem of ascertaining the proper amount of water to be applied to a given area of land, nor, in fact, to any other practical problem.

The difficulties involved in the application of this method are illustrated by the figures in the following table in which it is assumed that each of two farmers, A and B, applies succeeding increments of labor and capital to an acre of land, and that Farmer B always secures 25 per cent. less product on the same grade of land with the same expenditure. When Farmer A must pay a rent of $5 per acre for the use of land, he can (according to this table of returns) secure the greatest net profit per unit of labor and capital by expending $12.50 per acre; but the net profit per acre of land is greatest when $17.50 is expended. In this case Farmer A will have

to choose between the maximum net profit per acre and the maximum net profit per unit of expenditure for labor and capital. In case he should find that the same amount of managerial activity is required per unit of land regardless of the intensity of culture, he should spend $17.50 per acre; but if the same amount of managerial activity is required per unit of labor and capital whether expended upon a larger or a smaller area, then his best interests are conserved by seeking the maximum net profit per unit of labor and capital, for this would enable him to win the largest total profit from the business.

Expenditure per Acre for Labor and Capital	Value of Product Secured by Farmer		Increment of Product Due to an Increase in Expenditure of $2.50		Net Return per $1.00 of Expenditure, with Rent at $5.00 per Acre*		Net Return per Acre, i.e., Return minus Costs in Labor and Capital	
	A	B	A	B	A	B	A	B
$ 5.00	$ 9.00	$ 6.75	$ 5.00	$ 3.75	$ 0.80	$ 0.35	$ 4.00	$ 1.75
7.50	15.00	11.25	6.00	4.50	1.33	0.83	7.50	3.75
10.00	19.53	14.65	4.53	3.40	1.45	.965	9.53	4.65
12.50	23.33	17.50	3.80	2.85	1.47	1.00	10.83	5.00
15.00	26.33	19.75	3.00	2.25	1.42	.983	11.33	4.75
17.50	28.90	21.68	2.57	1.93	1.37	.953	11.40	4.18
20.00	31.00	23.25	2.10	1.57	1.30	.912	11.00	3.25

*The net return per dollar of expenditure for labor and capital is ascertained by subtracting the rent from the gross return and dividing the remainder by the number of dollars expended. This method is preferred to including the rent in the costs, for the reason that the rent comes out of the product as a rule, and is not commonly looked upon as an expense of production; and again, the money paid as rent, even if it were paid in advance and looked upon as an expense of production, does not make a demand on the managerial activity of the farmer in the way that expenditures for labor and capital do.

It is true that, if the rent were always put at just the requisite figure in this illustration, the degree of intensity which would yield the farmer the largest net profit *per acre* would be that which would yield him the largest net profit *per unit of labor and capital.* And if it were true that all farmers made the same rate of profit per composite unit of land, labor, and capital they manage— that is, if the quality of the management were always the same—then competition would drive rent up to the point where there would be only enough to pay costs, including the standard wages of superintendance, and the degree of intensity would be the same whether the farmer looked to the maximum average net product per unit of investment upon the land or to the maximum net profit per unit of land; but when we recur to the fact that there are variations in the quality of the management, and that the farmer is the residual claimant in this enterprise whose profits are larger or smaller accord-

ing as he is more or less successful as a manager, the problem becomes very much more complex.

Let us note the position of the two farmers, A and B, in the above table. When a rent of $5 is charged for the land, they both find that after paying the rent they have the maximum average net return per unit of investment in labor and capital when they each expend $12.50 per acre. This is also the degree of intensity which enables Farmer B to secure the maximum net return per acre of land but Farmer A can get a larger net return per acre of land by applying $17.50 per acre. Five dollars is, however, all that Farmer B can pay for the land; even then it is only as a laborer that he secures an income from which to live. It is fair to assume that Farmer A will not have to pay appreciably more rent for the use of the land than will Farmer B; and it will never be true, therefore, of the farmer whose managing ability is of superior quality, that it is the same thing whether he applies labor and capital to a given amount of land until the product attributable to the last increment of labor and capital is just sufficient to pay its cost (which is equivalent to the maximum net profit per unit of land), or whether he applies land to a given amount of labor and capital until the product attributable to the last increment of land is just sufficient to pay for the use of that increment of land (which is equivalent to the maximum net profit per unit of labor and capital).

If the reader has followed thus far, he will understand why the writer conceives the problem to be a complex one. If the farmer could be sure that the demands upon him as manager would vary with the number of laborers employed, then he could secure the largest total net profit by applying land to any given number of laborers until the product attributable to the last increment of land is just sufficient to pay its rent, or, what is the same thing, by seeking the maximum net profit per unit of labor. In actual practice, however, there are certainly many exceptions to this. It may help in solving the problem to classify the factors according as their increase does or does not make a proportional increase in the demand for managerial activity. The aim should then be to secure the maximum net profit per unit of the former class.

So far as the available evidence is concerned, it may quite as well be true in the application of water to land that a farmer can operate a given amount of labor and capital without regard to the quantity of water used or to the area to which it is applied. It

would seem, therefore, that we can go no farther here than to say that the farmer should not increase the quantity of water per acre after the point is reached where, due to diminishing returns per succeeding unit, the increment of water could be made to add more to his total net profits by adding it to other land. In order that any satisfactory conclusion shall be reached on this subject, it is necessary to carry out experiments and to have a very careful system of accounting such as will show the relative profitableness of different combinations of the factors of production.

The statement may be true that the farmer who is free to use his water supply as he pleases will find it to his economic self-interest to cease to increase the quantity of water applied to a given area, before the point is reached where the final increment of water would add more to his net profit if applied to other land, and it may be that in so doing he adds most to the total wealth of the country; yet the problem remains of developing a system of accounting which will enable the farmer to attain this ideal, and this duty devolves upon the state.[5]

III. THE INFLUENCE OF LAWS AND INSTITUTIONS ON THE ECONOMICAL USE OF WATER

Water rights under streams.—In formulating laws and institutions to regulate the use of water, it is important that, so far as possible, the regulation should make it to the interest of the farmer to strive after the highest social economic ideal, or, in other words, harmonize individual and social interests. Under present irrigation institutions there are two methods of granting the use of water. One is to grant a definite quantity of water which may be used where the grantee may choose and on any quantity of land he may choose; the other method is to grant sufficient water to irrigate a specific tract of land of a given area, with a maximum limit as to the quantity of water which may be taken. Irrigation authorities are not agreed as to the relative merits of these two systems. The attach-

[5] The problem of ascertaining the most profitable degree of intensity of culture as well as that of crop selection is one which demands attention in all lines of agricultural production in this day of increasing land values. The United States Department of Agriculture and some of the state experiment stations are commencing to work on these problems. It is expected that the results will be highly interesting to economists as throwing light upon some unsettled questions in economic theory, as well as beneficial to the agricultural interest.

ment of the water right to a specific tract of land has been objected to because, if strictly adhered to, it might require a farmer to use his water upon relatively unproductive lands; whereas, if he were free to exercise a second choice, he might use better land and add more to his income and to that of the nation. On the other hand, so closely interrelated are the interests of the different farmers on the same stream, owing especially to the effects of return seepage, that perfect freedom to change the place of using water may endanger the rights of others; and again it is claimed that where rights are not attached to the land there is great danger that the rights of earlier appropriators will be expanded to the detriment of later appropriators. In Wyoming, where the law of 1890 attached the water definitely to a specific piece of land, experience has emphasized the advisability of allowing transfers of rights from one piece of land of a given area to another of equal area, where the owner of the right is clearly to be benefited and where the interests of others are not injured. On the other hand, in Colorado there was no statutory regulation of the transfers of water rights prior to 1901, and yet in that state, as throughout the arid West, the courts have declared against transfers wherever it has been proved that others have been injured thereby. At the present time transfers are closely restricted in Colorado. While experience has proved the desirability of granting transfers of water rights from one piece of land to another in order that farmers may use water to better advantage, it has likewise demonstrated the wisdom of regulating such transfers in such a manner as will protect the interest of other farmers.

Regarding the relative merits of granting a specific quantity of water, as is the practice in Colorado, and granting sufficient to irrigate a given area of land, there are wide differences of opinion. It is very generally believed that the farmers will use the water more economically if it is secured in fixed quantities, without reference to the extent of the area to be irrigated, than where the area is the fixed unit. For example, if the farmer has a fixed quantity of water which he is free to use as he pleases, he will cease to add another increment of water to a given area when this water will yield him a greater net profit when applied to other land which would otherwise be left unirrigated. On the other hand, if the farmer has a right to sufficient water for a given area, he will desire to add succeeding increments of water to that given area so long

as each addition will result in an increase in his total net profits, when nothing is counted as the cost of the final increment of water.

The author of the Wyoming system recognizes that water will be used more economically when paid for by the unit quantity than when paid for by the acre irrigated regardless of the quantity used.[6] This is equivalent to saying that where a farmer has the right to the use of a specific quantity of water, without regard to the number of acres of land on which it is to be used, he will use the water more economically than he would if he had a right to irrigate a given number of acres of land without regard to the quantity of water used per acre.

But the author of the Wyoming system realized at the same time that, especially where agriculture by irrigation is first being established and where water is plentiful, there were other questions which were of more immediate importance than the highest degree of economy in the use of water. From the experience of other states where irrigation had longer been practiced, he had learned that where water rights were granted in cubic feet per second, without regard to the area of land on which it was used, no administrative system had been developed to keep the earlier appropriators from establishing rights to much more water than they were actually using. This led to a great injustice in later years; for, after later appropriators had established themselves by improving their farms, they found that the earlier appropriators had a legal means of expanding their diversions from the stream to such an extent as to leave the later appropriators without water.

The injustice of excessive rights which enabled the earlier appropriators to expand their diversions, enrich themselves, and impoverish their neighbors, was uppermost in the mind of the author of the Wyoming system, and his aim was to avoid this injustice. As a system of water administration in a country where the water rights are first being acquired, and where water has not become so valuable as to make economical use a very important factor, the system seems to be highly desirable. The question arises, however, if this system will prove most satisfactory after the rights to the entire water supply have been established and water has come to have a very high value placed upon it.

It would seem to be true that the interest of the state which

[6] Elwood Mead, *Irrigation Institutions*, pp. 133, 134; and U. S. Department of Agriculture, Office of Experiment Stations, *Bulletin No. 86*, p. 21.

grants the water would lead to a restriction in the quantity of water which would be turned into the ditches of the farmers, and in this manner force the farmers to use the water in that manner which conforms to the social ideal of economical use. In order to accomplish this result, it would be necessary however, for the state to ascertain, by a careful system of experimentation and accounting, the most economical use of water in every locality and for every crop produced in each locality, and then to limit the water-supply accordingly. In favor of this means of securing economy in the use of water it is argued that the state will have to carry on the experiments in any case; for these experiments are too difficult and too expensive to be carried out by the individual farmers. It may well be questioned, however, if it would not be much cheaper, lead to less friction, and be more stimulating to the intelligence of the farmers, to develop a system of accounting and teach the farmers to ascertain for themselves when they are securing the best results, and then so to frame the laws regulating the use of water that, when the farmer follows his own interest within the limits of the law, the best interests of society will be conserved. When the rights have been established, and a complete and rigid system of distribution has been developed, the dangers from excessive appropriation tend to pass away, and it would seem the simplest solution of the problem to continue granting each farmer, or his grantee, the quantity of water he has been receiving for many years, leaving him to use it on more or less land as seems most economical.

HENRY C. TAYLOR

UNIVERSITY OF WISCONSIN